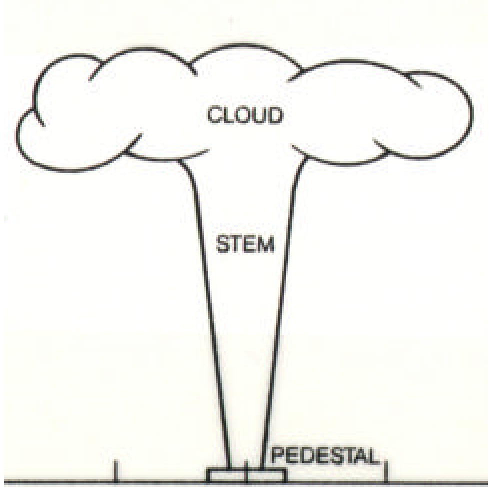
EC3630 Radiowave Propagation

ATMOSPHERIC NUCLEAR EFFECTS

by Professor David Jenn



(version 1.0)

Atmospheric Nuclear Effects (1)

The effect of a nuclear blast on the atmosphere is a complicated function of 1) number of detonations, 2) size of blasts, 3) altitudes, and 4) latitude and longitude. Low altitude bursts (< 40 km) loft large quantities of dust from the surface into the air. Blasts at intermediate altitudes (40 km to 100 km) and high altitudes (> 100 km) affect the state of the ionosphere and can have severe impact on satellite to ground communications and radar. Highly ionized regions reflect and attenuate. A single blast can be used to “blind” a radar so that it cannot detect and track other incoming missiles.

Some effects on electromagnetic propagation include:

1. <u>Attenuation</u> – Reduces signal-to-noise ratio (SNR) and therefore detection ranges and communication distances. Degradation of the signal to noise ratio reduces the ability of a radar to discriminate between real targets and decoys.
2. <u>Refraction</u> – Leads to tracking errors for radar; “dead” spots for communications
3. <u>Scintillation</u> – Fluctuations in amplitude and phase due to local variations in the refractive index tend to “randomize” signal phase and therefore limits processing techniques used to build the signal (e.g., integration and correlation).
4. <u>Backscatter</u> – Backscattered signals are a form of interference or clutter. They can be mistaken for a target or mask true targets.

Most of this material is taken from *Capabilities of Nuclear Weapons Manual (EM-1)*, DNA, Chapters 9 and 12.

Atmospheric Nuclear Effects (2)

In a vacuum the flux of the radiated energy would decrease by the inverse square law. In the atmosphere, collisions and scattering processes absorb energy and produce ionization.

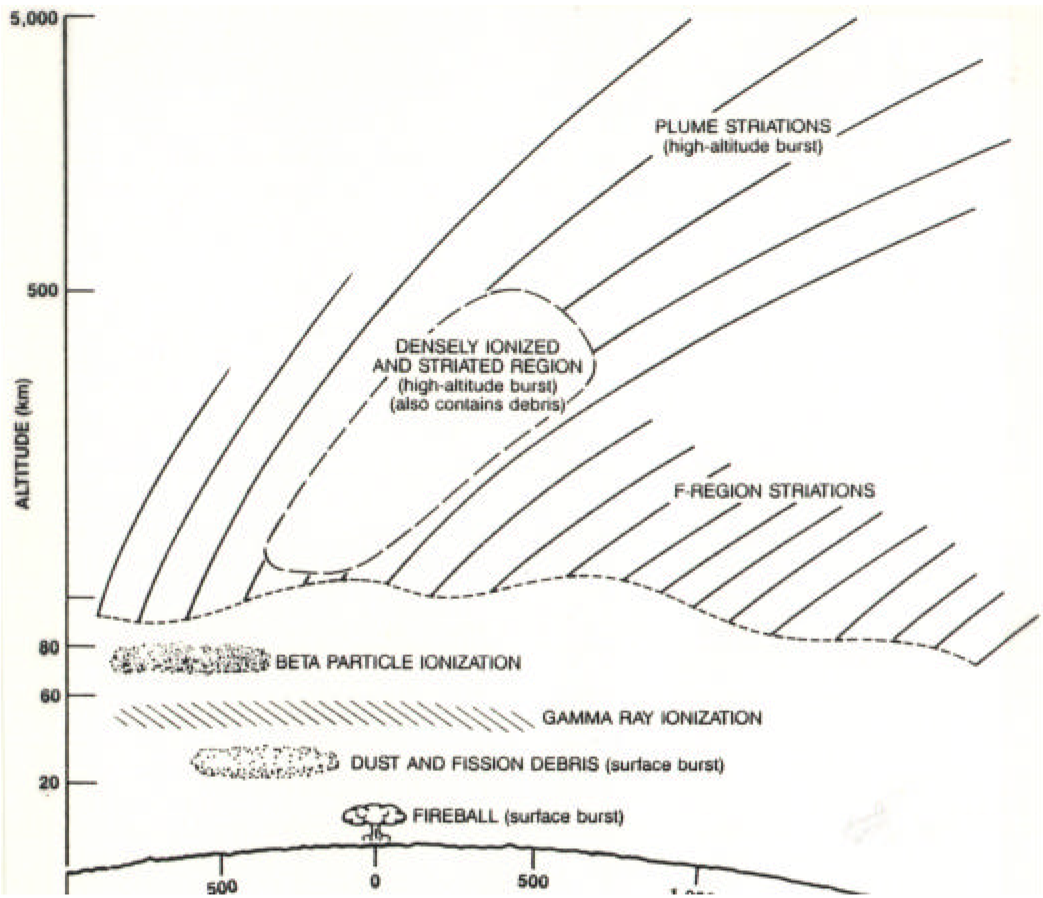
Energy from a nuclear detonation is emitted in several forms (particles and debris) that result in ionization of the atmosphere: 90 to 95% is prompt radiation (within the first microsecond); 5 to 10% is delayed radiation from radioactive decay (gamma rays and beta particles = high-energy electrons).

The stopping altitude: These are the altitudes for radiation entering the atmosphere from above the altitude where mass penetrated equals the reciprocal of mass absorption coefficient.

Particle	Stopping Altitude (km)
Prompt X-rays	80
Prompt neutrons	25
Debris	115
Delayed gamma rays	25
Delayed beta particles	60

If detonation occurs below the stopping altitude for a particular particle, then most of its radiation is contained locally (limited ionization).

Atmospheric Nuclear Effects (3)



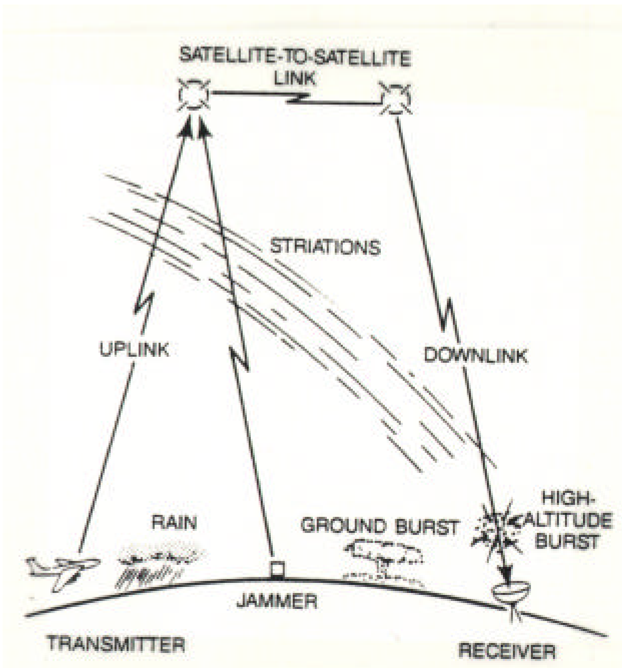
The figure illustrates of some blast effects on the atmosphere:

For low altitude bursts much of the energy goes into the dust and debris cloud, which have a well-defined shape.

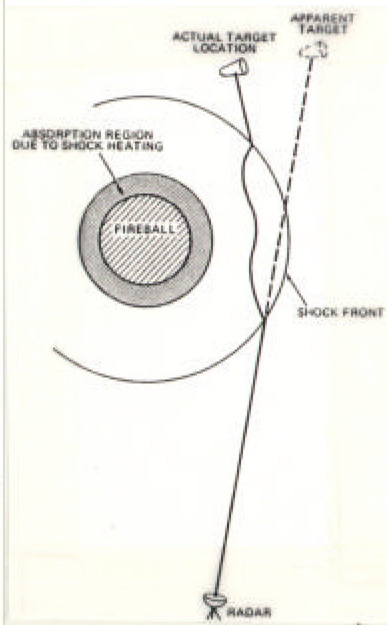
The geomagnetic field is important for high altitude bursts. High energy particles can escape to very large distances. The fireball striates into a field-aligned ionization structure. The plume striations can be long lasting.

Atmospheric Nuclear Effects (4)

Attenuation and scintillation



Refraction



These figures depict some of the nuclear effects on communication and radar systems:

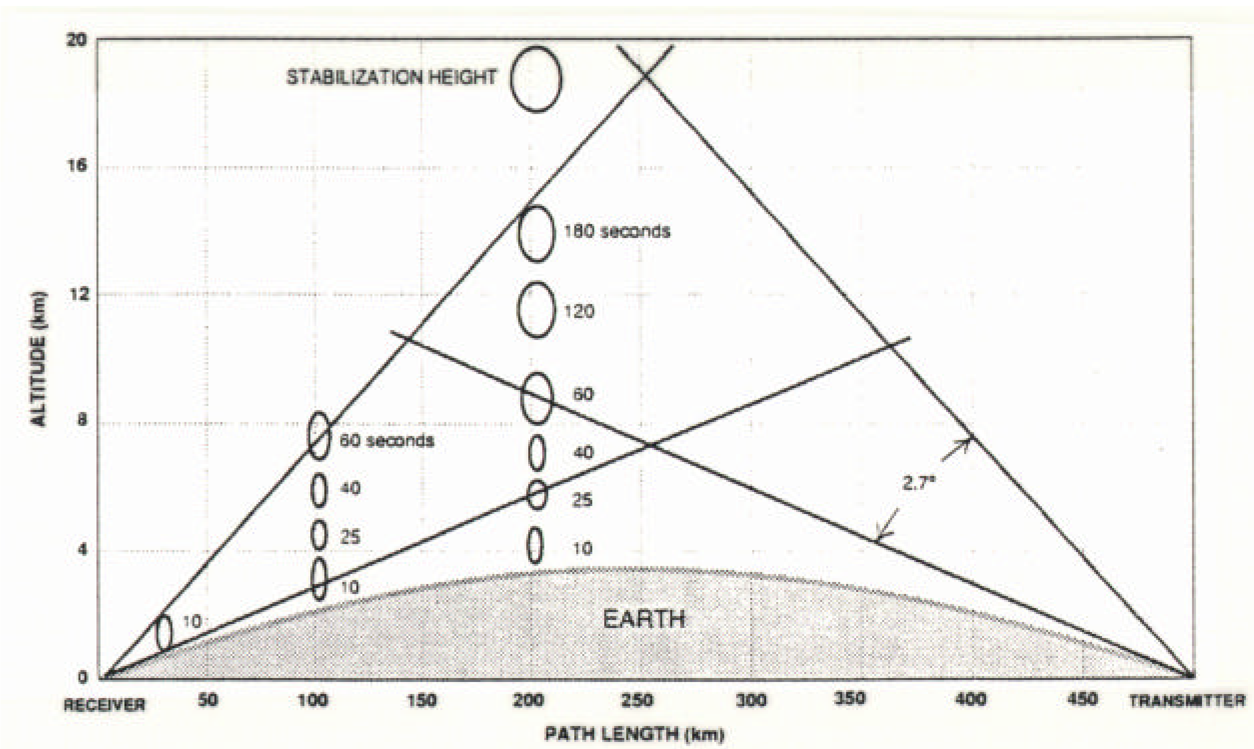
Attenuation and scintillation due to dust (low altitude blast).

Attenuation, refraction, and scintillation due to the fireball (blast at all altitudes).

Attenuation, refraction, excess time delay, Faraday rotation, and scintillation due to ionization and the formation of striations (mid and high altitude blasts).

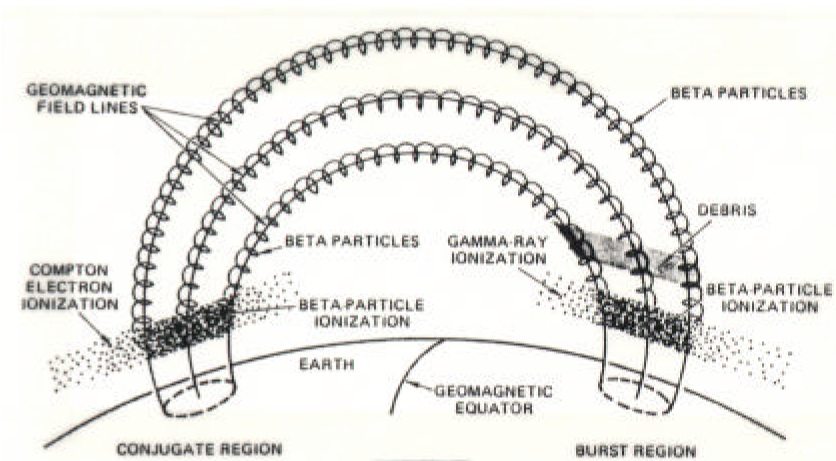
Atmospheric Nuclear Effects (5)

Height and expansion of the fireball, showing how it might possibly fill a radar antenna's field of view. The fireball emits noise that increases the antenna temperature, T_A (recall that $T_s = T_A + T_e$)

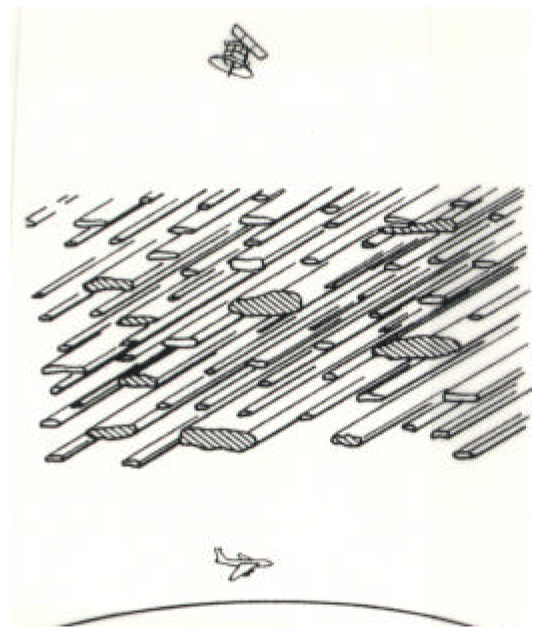


Atmospheric Nuclear Effects (6)

For blasts above about 90 km, the fireball ionization breaks up into very long geomagnetic-field-aligned striations (layers).



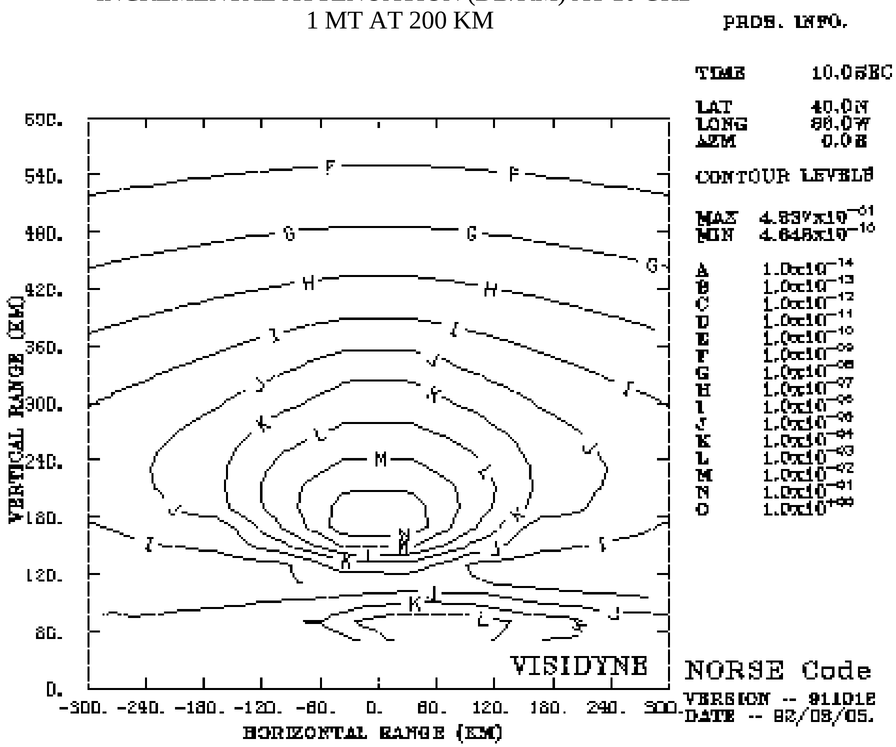
Striations increase the attenuation and scintillation encountered by satellite to ground systems.



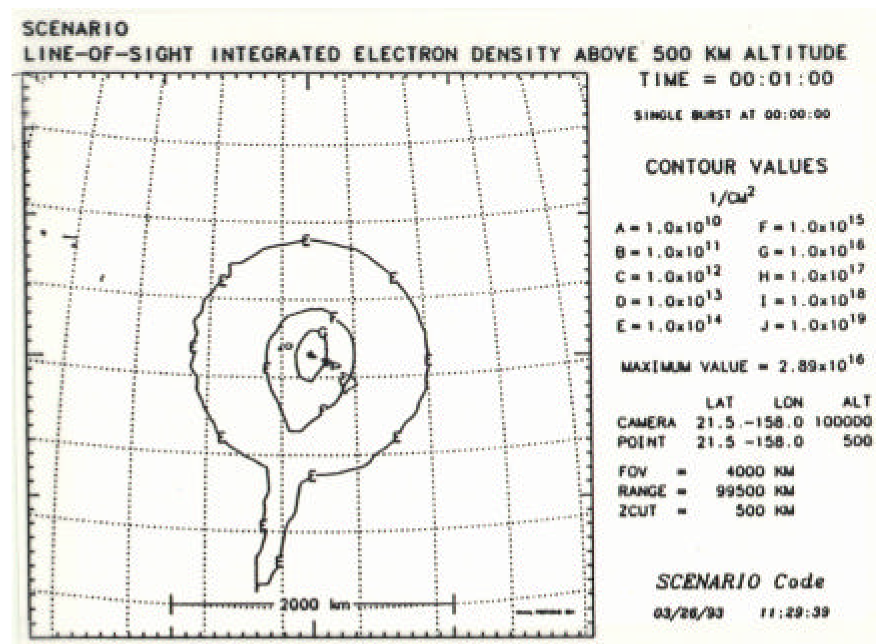
Atmospheric Nuclear Effects (7)

Simulation results (attenuation) from the NORSE code

INCREMENTAL ATTENUATION (DB/KM) AT 10 GHz
1 MT AT 200 KM



Simulation results (TEC) from the SCENARIO code



Atmospheric Nuclear Effects (8)

Ray trace plots showing reflection of waves from the plasma.